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**(54) MAGNETORHEOLOGICAL FLUIDS AND METHODS OF MAKING THEREOF**

MAGNETORHEOLOGISCHE FLÜSSIGKEITEN UND HERSTELLUNGSVERFAHRENS  
FLUIDES MAGNETO-RHEOLOGIQUES ET PROCEDES DE PRODUCTION

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**EP 0 636 273 B1**

**Description****FIELD OF THE INVENTION**

5 This invention relates to magnetorheological fluids, and more particularly to fluids containing a suspension of material which will change the fluid properties when acted on by a magnetic field, and methods for making such fluids.

**BACKGROUND OF THE INVENTION**

10 Fluids containing magnetic material are known in the art. Such fluids are designed to change viscosity or other fluid properties upon application of a magnetic field to the fluid. Typical uses of known magnetic fluid compositions have included shock absorbers, clutches, and actuating modules. However, prior art fluids have suffered from several disadvantages. Prior art fluids generally are not useful over a wide range of temperature. Known magnetic fluids also have suffered from instability of the magnetic particles in suspension. Such instability can include settling of the particles  
 15 over time due to gravitational forces and/or agglomeration of the particles in the fluid suspension.

Shtarkman, U.S. Patent No. 4,992,190, describes a fluid responsive to a magnetic field comprising magnetizable particulate, silica gel as a dispersant and a vehicle. Shtarkman discloses a fluid composition comprising 20% by weight of silicone oil and 80% by weight of a mixture of carboxyl iron (99% by weight) and pre-dried silica gel (1% by weight). Shtarkman discloses that such a fluid is useful as the dampening fluid in a shock absorber. Shtarkman discloses that  
 20 reduced magnetic particles can have an insulation coating (such as iron oxide) to prevent particle-to-particle contact, eddy currents or dielectric leakage.

Fluids such as those described by Shtarkman have limited commercial applicability. The silicone oil vehicle is a poor lubricant, particularly on steel surfaces, and must be combined with lubricants and mineral oils to overcome this disadvantage. Moreover, the high compressibility of silicone oils is undesirable since it increases the time for system  
 25 response to a magnetic field. Additionally, the silicone oils do not dissolve surfactants easily, precluding the use of non-organic stabilizers.

Chagnon, U.S. Patent No. 4,356,098, describes a ferrofluid composition comprising a colloidal dispersion of finely-divided particles in a liquid silicone-oil carrier and a dispersing amount of a surfactant which comprises a silicone-oil surfactant containing a functional group which forms a chemical bond with the surface of the particles and a tail group  
 30 which is soluble in the silicone-oil carrier. Fluids such as those disclosed by Chagnon suffer from an inability to viscosity to a sufficient degree upon application of a magnetic field. Such fluids generally change in viscosity by a factor of about two, which is considered unacceptable for many applications.

US-A-Re. 32, 573 relates to a ferrofluid composition and a process for the production thereof.

**OBJECTS AND SUMMARY OF THE INVENTION**

In light of the foregoing, it is an object of the invention to provide a stable magnetorheological fluid. It is a further object of the invention to provide a magnetorheological fluid which is stable over a range of temperature.

It is a further object of the invention to provide a magnetorheological fluid in which the magnetic particles do not  
 40 settle or agglomerate over time.

It is a further object of the invention to provide a magnetorheological fluid which responds quickly to application of a magnetic field.

Accordingly, the present invention provides a magnetorheological fluid composition comprising first particles comprising a magnetosoft material; a stabilizer; and a carrying fluid comprising an aromatic alcohol, a vinyl ether and an  
 45 organic solvent, wherein the first particles have adsorbed on their surface relatively smaller in size second particles having their own magnetic moment and comprising a magnetosolid material of oxidized magnetite or chromium dioxide, and the carrying fluid is present in a proportion of at least 0.278 parts by weight per part of the first and second particles combined. The invention further comprises a method for making a magnetorheological fluid composition comprising a method of making a stable magnetorheological fluid composition comprising preparing a carrying fluid comprising a  
 50 vinyl ether, an aromatic alcohol and an organic solvent or diluent carrier such as kerosene; preparing a first carrying fluid composition comprising first particles of a magnetosoft material, a stabilizer and a first sample of the carrying fluid; preparing a second carrying fluid composition comprising second particles having their own magnetic moment and comprising a magnetosolid material of oxidized magnetite or chromium dioxide and a second sample of the carrying fluid; and admixing the first carrying fluid composition and the second carrying fluid composition. The magnetorheological fluid composition of the present invention comprises a non-colloidal ferromagnetic powder suspended in a carrying fluid which contains a stabilizer.

The ferromagnetic particles of the invention are a mixture of coarse magnetosoft particles and fine magnetosolid particles. The magnetosoft particles preferably are made from carbonyl iron. The magnetosoft particles are generally

spherical in shape. A preferred particle size range is about 1 to about 10  $\mu\text{m}$ , though broader ranges are suitable. It is more important that the magnetosoft particles be proportionately larger than the magnetosolid particles. Preferably, the magnetosoft particles are at least about ten times larger than the magnetosolid particles.

The magnetosolid particles preferably are made from iron oxide or chromium dioxide. The magnetosolid particles are anisodiametric in shape. A preferred particle size range is about 0.1 to about 1.0  $\mu\text{m}$ , though relative size to the magnetosoft particles is considered more important to achieving the properties of the invention.

Magnetosoft carbonyl iron particles are produced by thermal decomposition of pentacarbonyl iron ( $\text{Fe}(\text{CO})_5$ ). Preferred carbonyl iron particles are commercially marketed powders used in conjunction with radioengineering equipment, such as those sold under Russian trademarks P-10, P-20, P-100, or those marketed by GDS BASF under the trademarks SF, TH, E. Iron oxide needle-like magnetosolid particles can be produced by oxidation of a magnetite such as  $\text{Fe}_3\text{O}_4$ . Chromium dioxide particles preferably are formed by the decomposition of chromium anhydride ( $\text{CrO}_3$ ) under high pressure in the presence of oxygen.

The magnetosolid particles are adsorbed onto the surface of the magnetosoft particles, imparting to the magnetic particles a brush-like effect. The magnetosolid particles are preferably small, needle-like magnets which attach at one end to the more coarse magnetosoft particles. Adsorption of magnetosolid particles onto magnetosoft particles has been shown to give the resulting fluid composition higher stability and greater relative viscosity change upon application of a magnetic field. Preferably, the magnetosoft particles are multidomain, that is, they are randomly distributed in a volume of liquid, and have no residual magnetization. The magnetosolid particles are preferred to have a needle-like shape and have their own magnetic moments, in order to provide the brush-like effect described above with the magnetosoft particles.

The carrying fluid of the invention is made from an organic solvent or diluent carrier, an aromatic alcohol, and a vinyl ether. A preferred organic solvent is a liquid hydrocarbon such as kerosene. The organic solvent preferably has low volatility, good anticorrosion properties, low toxicity, and high flash temperature and temperature of self-ignition. A preferred aromatic alcohol is  $\alpha$ -naphthol ( $\text{C}_{10}\text{H}_7\text{OH}$ ). A preferred vinyl ether is polyvinyl-n-butyl ether ( $(\text{CH}_2=\text{CHOC}_4\text{H}_9)_n$ ). The aromatic alcohol and vinyl ether preferably contain one or more of the following properties: solubility in the organic solvent; low freezing temperature (preferably below about  $-100^\circ\text{C}$ ); ability to thicken the organic solvent; and resistance to mechanical loading (preferably up to about  $10^6$  Pascals shear stress under flow). The aromatic alcohol and the vinyl ether are dissolved in the organic solvent to form the carrying fluid.

Other components can also be added to the carrying fluid, such as antifoaming agents, such as polysiloxane compounds, antiwear agents, such as tricresylphosphate ( $(\text{CH}_3\text{C}_6\text{H}_4\text{O})_3\text{PO}$ ).

The addition of an aromatic alcohol and a vinyl ether to the organic solvent creates a carrying fluid having a higher viscosity, greater lubricant properties and greater protection against breakdown of the organic solvent than the organic solvent alone. Preferably, the carrying fluid contains 90 to 95 parts by weight organic solvent, 0.01 to 0.10 parts aromatic alcohol, and 4.9 to 9.99 parts vinyl ether. A particularly preferred carrying fluid composition comprises 92.75 weight percent kerosene, 0.05 weight percent  $\alpha$ -naphthol, and 7.2 weight percent polyvinyl-n-butyl ether.

In most preferred embodiment of the invention, a stabilizer is used in addition to the carrying fluid to provide added stability to the fluid composition.

Preferred stabilizers include unhydrated, inorganic silicone compounds. A particularly preferred stabilizer is AEROSIL ( $\text{SiO}_2$ ).

The stabilizer particles preferably are approximately 0.005 - 0.015  $\mu\text{m}$  in diameter and are preferred to be about one-tenth to two-tenths the size of the magnetosolid particles. The relatively small diameter of the stabilizer particles results in the particles having a relatively large surface area. A stabilizer particles surface area of about 350 to 400  $\text{m}^2/\text{g}$  is preferred.

The stabilizer particles can be spherical in shape and preferably are non-porous. The stabilizer particles are designed so that in a shear flow, the structure formed by the particles are reversibly deformed. Preferably, the stabilizer is present in an amount of about 4 to 9 weight percent of the carrying fluid.

The magnetorheological fluid composition of the invention preferably is made using a multi-step process comprising admixing the carrying fluid ingredients, adding a stabilizer and magnetosoft particles to a first admixture of carrying fluid, adding magnetosolid particles to a second admixture of carrying fluid, and combining the two magnetic particle-containing carrying fluid compositions. The carrying fluid preferably is formed by dissolving the vinyl ether and aromatic alcohol in kerosene at ambient conditions.

The first carrying fluid admixture contains 5 to 25 parts by weight of magnetosoft particles to 10 parts of carrying fluid, and formed under continuous mixing. The stabilizer preferably is injected into the first carrying fluid admixture by use of a pulverizer.

A sufficient amount of stabilizer is added until a gelatinous composition is obtained, typically about 5 to 15 weight percent of the first carrying fluid admixture. Then the magnetosoft particles are added to the composition, which is homogenized, such as with a ball mill. Ball milling will minimize agglomeration of the magnetosoft particles which may occur upon addition to the composition.

The magnetosolid particles are added to the second admixture of carrying fluid and homogenized, such as by agitation. It is preferred that about 1 to 15 parts by weight magnetosolid particles per 10 parts by weight carrying fluid be present. Preferably, a surfactant is employed in this stage of the process to facilitate complete dispersion of the magnetosolid particles. The surfactant preferably is a fatty acid, with oleic acid being particularly preferred. The surfactant can minimize coagulation of the dispersed magnetosolid particles, and to aid in stably dispersing the particles in suspension. Preferably, less than 5 weight percent surfactant is employed in the second carrying fluid admixture, with less than one percent particularly preferred.

The two particle-containing carrying fluid mixtures are combined and homogenized. A ball mill is suitable for this purpose. Preferably, approximately 5 to 10 parts by weight of the first carrying fluid mixture, containing the magnetosolid particles, is added per 100 parts by weight of the second carrying fluid mixture. The resultant suspension is stable and responsive to application of a magnetic field.

Magnetorheological fluids of the present invention can be used in a variety of applications, such as polishing, seals, casting technology, controlled heat carriers, drives, clutches, hydraulic systems, and vibration systems (such as shock absorbers), including in conventional applications already known in the art. The fluids can be used in a variety of polishing applications such as optical lens polishing, and polishing of ceramics, the inner surfaces of tubes and pipes, and semiconductor materials. The fluids are particularly suitable for polishing objects having irregular shapes. The fluid can be used in heat carrier applications such as heat exchangers and audio speakers. Typical drive systems which can employ the fluid of the invention include robotics and actuating modules. Other applications for magnetorheological fluids known in the art may also take advantage of this novel composition.

In a lens polishing application, the composition, which can optionally include abrasive polishing particles, is contacted with a workpiece to be polished. Upon application of a magnetic field, the fluid viscosity changes and the fluid starts moving. In a preferred method of operation, the workpiece is immersed in the composition and the field is applied such that the fluid flows circularly around the workpiece. As the magnetic particles and/or the abrasive polishing particles contact the workpiece, the workpiece is polished. Using the composition of the invention, irregular-shaped objects and difficult to polish articles such as those made from crystal can be polished effectively.

#### EXAMPLE

A magnetorheological fluid of the invention was made using the following process. First, a carrying fluid sample was formed by dissolving 7.2 parts of polyvinyl-n-butyl ether 0.05 parts of  $\alpha$ -naphthol in 92.75 parts kerosene.

A first carrying fluid admixture is prepared by injecting AEROSIL ( $\text{SiO}_2$ ) A-380, manufactured by Industrial Association Chlorvinyl, Kalysha City, Ukraine, into the carrying fluid prepared as described above. Injection took place over an hour until a homogenous gelatinous system was obtained. Then, iron carboxide powder was added to the admixture. The entire admixture was homogenized in a ball mill over a period of 4 to 5 hours. The proportion of ingredients was iron carboxide powder (50 weight %), aerosil (7.5 weight %), carrying fluid (42.5 weight %).

Chromium dioxide powder, oleic acid and a second carrying fluid sample were mixed and homogenized for 4 to 5 hours in a universal agitator in the following proportions:

Chromium dioxide powder	- 36 weight %
Oleic acid	- 0.36 weight %
Carrying fluid	- 63.63 weight %

Next, the two magnetic particle-containing carrying fluid admixtures were combined and mixed in a ball mill for an hour to arrive at a final composition. 100 grams of the iron carboxide-containing admixture were added to 7.5 grams of the chromium dioxide powder-containing admixture. The resulting product exhibited changed viscosity, plasticity, elasticity, thermoconductivity, and electroconductivity in response to application of a magnetic field. The fluid was stable at temperatures of -50 to 120°C. The composition was tested in a cylindrical coaxial rotary viscometer supplied by a magnetic field inductor. The applied field intensity H was varied up to 80 kA/m, and the shear rate  $\dot{\gamma}$  was varied from 1.02 to 444.5 seconds<sup>-1</sup>. The response of the fluid viscosity to the magnetic field intensity is given in Table I below. It can be seen from Table I that increasing field intensity results in increasing viscosity at a given shear rate. The data in Table I also indicate that increasing shear rate results in generally lower viscosity at a given field intensity. Highest viscosity was obtained at low shear rate and high field intensity.

TABLE I

H, kA/m									
	0	12.7	24.2	35.0	43.6	48.2	62.0	77.0	84.0
$\dot{\gamma}, s^{-1}$	$\eta, Pa.s$								
1.02	0.81	5.32	31.94	51.86	87.76	135.6	438.8	492.0	585.1
1.84	0.54	3.23	36.85	29.32	56.44	76.24	249.2	300.6	329.9
2.97	0.39	2.27	11.79	20.41	38.10	50.80	158.8	190.5	208.7
5.42	0.33	1.49	6.99	11.49	23.48	29.97	89.91	107.3	117.4
9.10	0.29	1.03	4.56	9.13	14.72	19.72	63.27	78.48	85.35
16.45	0.27	0.91	2.63	5.35	8.56	12.68	39.53	49.41	50.23
27.70	0.24	0.73	1.71	3.40	5.44	8.16	25.76	32.07	34.51
49.40	0.22	0.49	1.08	2.03	3.19	4.81	15.66	20.79	22.14
82.30	0.18	0.34	0.71	1.31	1.99	2.91	10.37	13.77	15.06
147.80	0.17	0.26	0.48	0.86	1.24	1.84	6.64	8.69	9.64
246.0	0.14	0.19	0.32	0.56	0.77	1.08	4.05	5.29	5.78
444.5	0.12	0.14	0.20	0.32	0.44	0.59	2.21	2.92	3.13

### Claims

1. A magnetorheological fluid composition comprising:

first particles comprising a magnetosoft material;  
a stabilizer;

and a carrying fluid comprising an aromatic alcohol, a vinyl ether and an organic solvent, characterised in that the first particles have adsorbed on their surface relatively smaller in size second particles having their own magnetic moment and comprising a magnetosolid material of oxidized magnetite or chromium dioxide, and the carrying fluid is present in a proportion of at least 0.278 parts by weight per part of the first and second particles combined.

2. A magnetorheological fluid composition as claimed in claim 1, further comprising oleic acid.

3. A magnetorheological fluid composition as claimed in claim 1 or claim 2, wherein the second particles have a diameter in the range of from 0.1 to 1.0  $\mu m$ .

4. A magnetorheological fluid composition as claimed in any one of the preceding claims, wherein the first particles are made from carbonyl iron.

5. A magnetorheological fluid composition as claimed in any one of the preceding claims, wherein the first particles have a diameter in the range of from 1 to 10  $\mu m$ .

6. A magnetorheological fluid composition as claimed in any one of the preceding claims, wherein the second particles are needle-like.

7. A magnetorheological fluid composition as claimed in any one of the preceding claims, wherein the aromatic alcohol is  $\alpha$ -naphthol, the vinyl ether is polyvinyl-n-butyl ether and the organic solvent is kerosene.

8. A magnetorheological fluid composition as claimed in any one of the preceding claims, wherein the stabilizer is silicon dioxide.

9. A magnetorheological fluid composition as claimed in any one of the preceding claims, which comprises:

(a) from 20 to 70 parts by weight of the first particles;

- (b) from 0.5 to 20 parts by weight of the second particles;
- (c) from 4 to 9 parts by weight of a silicon dioxide stabilizer; and
- (d) from 25 to 55 parts by weight of a carrying fluid comprising from 5 to 10 weight percent polyvinyl-n-butyl ether, 0.01 to 1.0 weight percent  $\alpha$ -naphthol and 90 to 95 weight percent kerosene.

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10. A method of making a stable magnetorheological fluid composition characterised in that it comprises:

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- (a) preparing a carrying fluid comprising a vinyl ether, an aromatic alcohol and an organic solvent;
- (b) preparing a first carrying fluid composition comprising first particles of a magnetosoft material, a stabilizer and a first sample of the carrying fluid;
- (c) preparing a second carrying fluid composition comprising second particles having their own magnetic moment and comprising a magnetosolid material of oxidized magnetite or chromium dioxide and a second sample of the carrying fluid; and
- (d) admixing the first carrying fluid composition and the second carrying fluid composition.

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11. A method of making a stable magnetorheological fluid composition as claimed in claim 10, wherein the second carrying fluid composition further comprises oleic acid.

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12. A method of making a stable magnetorheological fluid composition as claimed in claim 10 or claim 11, wherein the first particles comprise carbonyl iron and the stabilizer is silicon dioxide.

13. A method of making a stable magnetorheological fluid composition as claimed in any one of the claims 10 to 12, wherein the organic solvent is kerosene.

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14. A ferromagnetic particle system suitable for use in a rheologic fluid comprising a first particle of magnetosoft carbonyl iron, characterised in that the surface of the first particle has adsorbed thereon relatively smaller in size needle-like second particles having their own magnetic moment and comprising a magnetosolid material of oxidized magnetite or chromium dioxide.

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#### Patentansprüche

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1. Magnetorheologische Fluidzusammensetzung, umfassend: erste Partikel, umfassend ein weichmagnetisches Material;

einen Stabilisator;  
und ein Trägerfluid, umfassend einen aromatischen Alkohol, einen Vinylether und ein organisches Lösungsmittel,

40

**dadurch gekennzeichnet,**

daß die ersten Partikel auf ihrer Oberfläche relativ kleinere zweite Partikel adsorbiert haben, die ihr eigenes magnetisches Moment haben und ein hartmagnetisches Material aus oxidiertem Magnetit oder Chromdioxid umfassen und das Trägerfluid in einem Anteil von mindestens 0,278 Gewichtsteilen pro Teil der kombinierten ersten und zweiten Partikel vorliegt.

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2. Magnetorheologische Fluidzusammensetzung nach Anspruch 1, welche weiterhin Oleinsäure umfaßt.

3. Magnetorheologische Fluidzusammensetzung nach Anspruch 1 oder 2, worin die zweiten Partikel einen Durchmesser im Bereich von 0,1 bis 1,0  $\mu\text{m}$  aufweisen.

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4. Magnetorheologische Fluidzusammensetzung nach einem der vorhergehenden Ansprüche, worin die ersten Partikel aus Carbonyleisen hergestellt sind.

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5. Magnetorheologische Fluidzusammensetzung nach einem der vorhergehenden Ansprüche, worin die ersten Partikel einen Durchmesser im Bereich von 1 bis 10  $\mu\text{m}$  aufweisen.

6. Magnetorheologische Fluidzusammensetzung nach einem der vorhergehenden Ansprüche, worin die zweiten Partikel nadelförmig sind.

7. Magnetorheologische Fluidzusammensetzung nach einem der vorhergehenden Ansprüche, worin der aromatische Alkohol  $\alpha$ -Naphthol ist, der Vinylether Polyvinyl-n-butylether ist und das organische Lösungsmittel Kerosin ist.
8. Magnetorheologische Fluidzusammensetzung nach einem der vorhergehenden Ansprüche, worin der Stabilisator Siliciumdioxid ist.
9. Magnetorheologische Fluidzusammensetzung nach einem der vorhergehenden Ansprüche, welche umfaßt:
  - (a) von 20 bis 70 Gewichtsteile der ersten Partikel;
  - (b) von 0,5 bis 20 Gewichtsteile der zweiten Partikel;
  - (c) von 4 bis 9 Gewichtsteile eines Siliciumdioxid-Stabilisators; und
  - (d) von 25 bis 55 Gewichtsteile eines Trägerfluids, umfassend 5 bis 10 Gew.-% Polyvinyl-n-butylether, 0,01 bis 1,0 Gew.-%  $\alpha$ -Naphthol und 90 bis 95 Gew.-% Kerosin.
10. Verfahren zur Herstellung einer stabilen magnetorheologischen Fluidzusammensetzung, dadurch gekennzeichnet, daß es umfaßt:
  - (a) Herstellen eines Trägerfluids, umfassend einen Vinylether, einen aromatischen Alkohol und ein organisches Lösungsmittel;
  - (b) Herstellen einer ersten Trägerfluid-Zusammensetzung, umfassend erste Partikel eines weichmagnetischen Materials, einen Stabilisator und eine erste Probe des Trägerfluids;
  - (c) Herstellen einer zweiten Trägerfluid-Zusammensetzung, umfassend zweite Partikel, die ihr eigenes magnetisches Moment aufweisen und ein hartmagnetisches Material aus oxidiertem Magnetit oder Chromdioxid umfassen, und eine zweite Probe des Trägerfluids; und
  - (d) Vermischen der ersten Trägerfluid-Zusammensetzung und der zweiten Trägerfluid-Zusammensetzung.
11. Verfahren zur Herstellung einer stabilen magnetorheologischen Fluidzusammensetzung nach Anspruch 10, worin die zweite Trägerfluid-zusammensetzung weiterhin Oleinsäure umfaßt.
12. Verfahren zur Herstellung einer stabilen magnetorheologischen Fluidzusammensetzung nach Anspruch 10 oder 11, worin die ersten Partikel Carbonyleisen umfassen und der Stabilisator Siliciumdioxid ist.
13. Verfahren zur Herstellung einer stabilen magnetorheologischen Fluidzusammensetzung nach einem der Ansprüche 10 bis 12, worin das organische Lösungsmittel Kerosin ist.
14. Ferromagnetisches Partikelsystem, geeignet zur Verwendung in einem rheologischen Fluid, umfassend einen ersten Partikel eines weichmagnetischen Carbonyleisens, dadurch gekennzeichnet, daß die Oberfläche des ersten Partikels darauf relativ kleinere nadelförmige zweite Partikel adsorbiert hat, die ihr eigenes magnetisches Moment aufweisen und ein hartmagnetisches Material aus oxidiertem Magnetit oder Chromdioxid umfassen.

# Revendications

1. Composition de fluide magnéto-rhéologique comportant : des particules d'un premier type, comprenant un matériau magnétique doux,
  - un stabilisant, et
  - un fluide porteur comprenant un alcool aromatique, un éther vinylique et un solvant organique,caractérisée en ce que les particules du premier type portent des particules d'un second type, de taille relativement plus petite, qui sont adsorbées à leur surface, qui ont leur propre moment magnétique et qui comprennent un matériau magnétique dur qui est de la magnétite oxydée ou du dioxyde de chrome, et en ce que le fluide porteur se trouve en une proportion d'au moins 0,278 partie en poids pour 1 partie en poids de l'ensemble des particules des premier et second types.
2. Composition de fluide magnéto-rhéologique conforme à la revendication 1, qui comporte en outre de l'acide oléique.

3. Composition de fluide magnéto-rhéologique conforme à la revendication 1 ou 2, dans laquelle les particules du second type présentent un diamètre de 0,1 à 1,0  $\mu\text{m}$ .
- 5 4. Composition de fluide magnéto-rhéologique conforme à l'une des revendications précédentes, dans laquelle les particules du premier type sont préparées à partir de fer-carbonyle.
5. Composition de fluide magnéto-rhéologique conforme à l'une des revendications précédentes, dans laquelle les particules du premier type présentent un diamètre de 1 à 10  $\mu\text{m}$ .
- 10 6. Composition de fluide magnéto-rhéologique conforme à l'une des revendications précédentes, dans laquelle les particules du second type sont aciculaires.
7. Composition de fluide magnéto-rhéologique conforme à l'une des revendications précédentes, dans laquelle l'alcool aromatique est de l' $\alpha$ -naphtol, l'éther vinylique est un poly(vinyl-n-butyl-éther) et le solvant organique est du kérosène.
- 15 8. Composition de fluide magnéto-rhéologique conforme à l'une des revendications précédentes, dans laquelle le stabilisant est du dioxyde de silicium.
- 20 9. Composition de fluide magnéto-rhéologique conforme à l'une des revendications précédentes, qui comporte :
  - a) de 20 à 70 parties en poids de particules du premier type,
  - b) de 0,5 à 20 parties en poids de particules du second type,
  - c) de 4 à 9 parties en poids de dioxyde de silicium, en guise de stabilisant, et
  - 25 d) de 25 à 55 parties en poids d'un fluide porteur comprenant
    - de 5 à 10 % en poids de poly(vinyl-n-butyl-éther),
    - de 0,01 à 1,0 % en poids d' $\alpha$ -naphtol, et
    - de 90 à 95 % en poids de kérosène.
- 30 10. Procédé de préparation d'une composition stable de fluide magnéto-rhéologique, caractérisé en ce qu'il comporte :
  - a) le fait de préparer un fluide porteur contenant un alcool aromatique, un éther vinylique et un solvant organique,
  - 35 b) le fait de préparer une première composition à base de fluide porteur, comportant des particules d'un premier type en un matériau magnétique doux, un stabilisant et une première fraction de fluide porteur,
  - c) le fait de préparer une seconde composition à base de fluide porteur, comportant des particules d'un second type qui ont leur propre moment magnétique et qui comprennent un matériau magnétique dur qui est de la magnétite oxydée ou du dioxyde de chrome, et une seconde fraction de fluide porteur, et
  - 40 d) le fait de mélanger les première et seconde compositions à base de fluide porteur.
11. Procédé de préparation d'une composition stable de fluide magnéto-rhéologique, conforme à la revendication 10, dans lequel la seconde composition de fluide porteur contient en outre de l'acide oléique.
- 45 12. Procédé de préparation d'une composition stable de fluide magnéto-rhéologique, conforme à la revendication 10 ou 11, dans lequel les particules du premier type comprennent un fer-carbonyle, et le stabilisant est du dioxyde de silicium.
13. Procédé de préparation d'une composition stable de fluide magnéto-rhéologique, conforme à l'une des revendications 10 à 12, dans lequel le solvant organique est du kérosène.
- 50 14. Système qui est une particule ferromagnétique appropriée pour être utilisée dans un fluide magnéto-rhéologique, comprenant une particule d'un premier type en un matériau magnétique doux qui est un fer-carbonyle, et caractérisé en ce que cette première particule porte, adsorbées sur sa surface, des particules d'un second type, aciculaires et de taille relativement plus petite, qui ont leur propre moment magnétique et qui comprennent un matériau magnétique dur qui est de la magnétite oxydée ou du dioxyde de chrome.
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